2011

Change Detection Ability in Naturalistic Scenes: Are Object Appearances or Disappearances Easier to Detect When Disappearances Should Be More Noticeable?

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Bachelor of Science in Psychology

John Carroll University

May 2009

submitted in partial fulfillment of requirements for the degree

MASTER OF ARTS IN PSYCHOLOGY

at the

CLEVELAND STATE UNIVERSITY

August 2011

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ABSTRACT

Onset primacy is a robust phenomenon in which appearance of new objects in a scene effectively captures observers' attention. The present study explored conditions under which object offsets may also capture observers' attention. We hypothesized that our visual attentional system is programmed by default to look for onsets of new objects. However, our attentional priority may be able to flexibly adapt to the detection of object offsets depending on what types of visual event better fulfills observers' behavioral goals. To test this hypothesis, an experiment was conducted in which participants were biased toward finding offset of an existing object. Results suggested that participants who experienced the bias detected offsets more quickly and accurately than participants who did not experience the bias, but still had shorter reaction times and higher accuracy on onset trials. Participants who were free from any biases performed better on onset trials than offset trials. Improved performance on offset trials in participants who experienced the offset bias support the idea that onset primacy may not be a hard-set rule and that observers may be able to give attentional priority to non-onset events in an adaptive manner.

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CHAPTER I

INTRODUCTION

People frequently fail to notice large changes in their environment. For example, failing to detect such changes may occur while viewing a film. An observer may not notice a discontinuity between camera shots, even if the camera angle does not change. Essentially, an object such as a jacket occupying a large area of the screen may "disappear" from one clip to the next, and many people would not notice. Failing to notice such changes is a surprising trend, considering how much information people think they process (Simons & Chabris, 2011). Specifically, this inability to notice such salient visual changes has been termed *change blindness* (Simons, 2005). It was first demonstrated by using an experimental model known as the flicker paradigm (Rensink, O'Regan, & Clark, 1997). In this paradigm, two images that are identical except for one change (e.g., an object such as a tennis ball and rock), "flicker" over each other in a continuous, alternating pattern. Rensink et al. found that it takes unexpectedly long for observers to detect the difference between the images, and suggested that people are blind to changes in their visual field when not actively attending to these objects in their environment. On the other hand, it has also been suggested that change blindness occurs not because of the lack of active attention, but because of our tendency to ignore the details of our visual field that are irrelevant to our goals (Triesch, Ballard, Mayhoe, & Sullivan, 2003). Although psychological mechanisms of change blindness have been a subject of an active debate in this manner, there is an emerging consensus that change blindness has to do with the deployment of observers' attention (Bubic, 2008).

Early studies on change blindness involved instances where a new object unexpectedly replaced another object, both in real-world settings (e.g., Simons & Levin, 2004) and in laboratory settings (e.g., Levin & Varakin, 2004). Change blindness research has more recently focused on different types of changes, rather than simply object replacement, in order to see under what conditions people are more or less susceptible to change blindness. Two important types of changes have attracted considerable attention: additions (onsets) of a new object and deletions (offsets) of a previously existing object, because they occur naturally in everyday situations (e.g. Cole, Liversedge, & Simon 2006; Cole, Kentridge, & Heywood, 2004). The present study extended previous work on object onsets and offsets by delving into the question of what specifically grabs people's attention, enabling them to be more resistant to change blindness.

In order to begin evaluating this question, it is helpful to consider findings of visual search studies that focused on visual attentional capture. In visual search studies, participants are generally instructed to look for a particular target stimulus among other symbols, shapes, or letters in a visual array. A group of visual search studies examined a viewing condition that is of particular importance to the present study. In these studies, the target stimulus was defined by an abrupt change in the search display: either an appearance of a new object (i.e., object onset) or a disappearance of a previously viewed object (i.e., object offset). A key finding from these studies is that an observer detects onsets of objects with greater speed and accuracy than offsets of objects (e.g., Yantis & Jonides, 1984). Yantis and Jonides explained the phenomenon, known as onset primacy, as instances in which onsets are more effective in capturing people's attention than offsets. Although other changes in visual properties such as luminance, quantity, and color are also produced during the onset of a new object, it seems that the object onset itself, rather than the other simultaneous visual changes, is what ultimately succeeds in capturing attention (Jonides & Yantis, 1988; but see also Hollingworth, Simons, & Franconeri, 2010).

Onset primacy has been previously brought into the research area of change blindness by Cole, Kentridge, Gellatly, and Heywood (2003). They found that observers were more resistant to change blindness when they experienced object onsets than offsets, presumably due to onset primacy. They demonstrated this by using what is known as the one-shot flicker paradigm. In this paradigm, participants were presented with two images successively, separated by a brief presentation of blank gray screen. The two images were identical except that either an addition of a new object or a deletion of an existing object took place in the second image. Participants were asked to detect the change in the second image as accurately as possible. Results indicated that participants were significantly more accurate in detecting the onset of a new object than the offset of an existing object, suggesting that object onsets are less susceptible to change blindness. Cole et al. (2003) first demonstrated superior accuracy in object onset detection in a change blindness context by using abstract computer-generated displays, as used in visual search studies. They then extended their results by using photographs of two-dimensional displays of real objects taken from an aerial perspective, showing that onset primacy in a change blindness paradigm is not restricted to stimuli similar to those used in visual search studies. Furthermore, Donaldson and Yamamoto (2011) replicated Cole et al's (2003) findings by using even more realistic three-dimensional scenes, providing further evidence that onset primacy exists in the context of change blindness. Thus, Cole et al. (2003) and Donaldson and Yamamoto (2011) helped to bridge the gap between visual search studies and change blindness studies, suggesting that onset primacy is a robust phenomenon observable across various domains of visual cognition.

Although Cole et al. (2003) and Donaldson and Yamamoto (2011) clearly demonstrated that onset primacy takes place in a variety of viewing conditions, including a change blindness paradigm, they did not provide any explanation as to why onsets are superior to offsets in effectively capturing visual attention. On one hand, there may be an evolutionary advantage for humans and non-human animals to detect object onsets faster or more accurately than other types of visual events for the purposes of survival and overall utility. For example, it is more beneficial for an animal to locate and avoid a predator entering its surroundings, than paying attention to when the predator leaves. Similarly, it is more important for automobile drivers to notice an obstacle suddenly enter their field of vision than attend to a pedestrian walking away. On the other hand, it is also advantageous for a mother to notice when her child is missing, or for a sales clerk to notice missing merchandise. Thus, from an evolutionary perspective, there are adaptive reasons for both onsets and offsets to capture visual attention. However, onsets seem to be the primary visual event to which attention will be directed.

The above discussion leads to our attentional modulation hypothesis that onset primacy results from the default mode of the human visual system that is set at paying increased attention to object onsets. This default mode is determined by the fact that detecting the appearance of new objects quickly and accurately is generally the most effective way of interacting with an environment. Thus, a key component of our hypothesis is that when detecting other types of visual events, such as object offsets, can be of higher priority, it is possible that observers flexibly adjust their attentional system to better detect these non-onset events. The aim of the present study was to test our attentional modulation hypothesis by creating a situation where observers are biased toward detecting object offsets. In an experiment, the bias in favor of object offset was induced in participants to assess whether object offsets can become less susceptible to change blindness compared to when participants have no such bias (i.e., they use their default mode of attention with which they naturally look for object onsets). The prediction of the present study was that participants' ability to detect offsets would be improved when the offset bias is induced. It was further predicted that their ability to detect onsets would be impaired under the offset bias due to a shift from the default attentional mode.

CHAPTER II

METHOD

2.1 *Participants*

Sixty people (18 men, 42 women) from the Cleveland State University community consented to participate in this study for partial course credit or monetary compensation. They ranged in age from 18 to 46 years (*M* = 23.1). Fifty-two participants (81.24%) showed right hand dominance according to the Edinburgh handedness inventory (Oldfield, 1971). All participants had normal or corrected-to-normal vision. Participants were treated according to the APA ethical guidelines.

2.2 *Materials*

Experimental stimuli presented to the participants in this study were color digital pictures that depicted a wooden round tabletop on which eight objects were placed in various arrangements. The objects used were toys and small household items that were approximately 4 cm in width, 2 cm in depth, and 3 cm in height. The tabletop was 38 cm in diameter and supported by a table base that was 75 cm tall. The objects were placed so that half were on the left side of the tabletop and half were on the right side. No object occluded another object, such that every object was visible in its entirety. The wall behind and to either side of the table was visible, as was the carpet on which the table stood. Digital pictures of the table were taken from an angle of approximately 30º, which provided a naturalistic view of the object arrangements. For examples of the stimuli, see Figure 1.

These images were presented on a computer screen that had a 17-inch liquid crystal display. The screen was positioned vertically in front of the participant. The distance between the participant and the screen was approximately 60 cm. The images were presented to occupy the entire screen and subtended approximately 35º x 40º of visual angle. When presented on the screen, the center of the tabletop was at the center of the screen. More precisely, the sagittal median line of the tabletop was approximately aligned with that of the screen so that the left and right halves of the tabletop corresponded to those of the screen.

2.3 *Design*

All participants went through two blocks of trials. In each block, participants viewed a series of 128 photograph pairs. Each pair constituted either an onset trial in which a new object was added to the second image or an offset trial in which one of the objects in the first image was deleted in the second image. The onset and offset trials were randomly intermixed. Each object was used the same number of times to create an onset trial or an offset trial throughout the experiment (i.e., all objects were presented an equal number of times throughout the experiment). The participant’s task was to detect the change as accurately and quickly as possible by indicating whether it occurred in the right half or the left half of the tabletop. The location of the change was counterbalanced such that in half the onset trials objects in the left side changed and in the remaining half the objects in the right side changed. The same was done for offset trials.

Participants were randomly assigned to one of three conditions used in the experiment that will be described in detail later. The only constraint to random assignment was that each condition had 20 participants. All conditions included a short practice session in the beginning of the experiment followed by two blocks of 128 trials. Stimuli used in the practice session were composed of different objects whose dimensions were similar to those used in the experimental blocks. They were also in a unique configuration that was not repeated in subsequent blocks. Photograph pairs used in the two experimental blocks depicted the same eight objects, but they appeared in different configurations in the two blocks. These manipulations ensured that participants were not influenced by any adventitious priming effects that can result from seeing particular objects or configurations more frequently (e.g., Chun & Jiang, 1998). The conditions differed as to whether and how participants experienced bias toward detecting object offsets. The bias was induced either during the first block of trials or before the practice session (details are described below). As such, not all conditions used the same practice session or first block, and therefore data from these practice and first block trials were not included in the analysis. On the other hand, the three conditions were identical in the second block in which critical data were collected.

2.3.1 *Neutral condition*. In this condition, no particular bias was induced in participants. In other words, it was expected that they would exhibit onset primacy because of using the default attentional mode. The practice session included one onset trial and one offset trial. The order of these two trials was randomly determined. Each experimental block had 64 onset trials and 64 offset trials that were also randomly intermixed. The same pairs of images were used for onset and offset trials within each block by reversing the order of their presentation. This manipulation ensured that the identical visual characteristics were present in onset and offset trials.

2.3.2 *Skewed ratio condition*. In this condition, the second block was identical to that used in the other two conditions. The offset bias was induced by showing participants more offset trials than onset trials in the first block. After receiving two practice trials (as in the neutral condition), participants saw 100 offset trials and 28 onset trials in the first block. Furthermore, the first 20 trials and the last 20 trials in the first block were offset trials while the remaining 88 trials were randomly intermixed. This manipulation was intended to give participants a strong impression that object offset was the primary type of change that they would encounter in the experiment. Seventy- two photograph pairs were used only as offset trials. Twenty- eight photograph pairs were used both during offset and onset trials by reversing the order of their presentation. This stimuli presentation was to ensure as much similarity in the design of the neutral condition as possible. The objects and side of the screen on which the change occurred were still counterbalanced.

2.3.3 *Skewed ratio with instruction condition*. In this condition, participants were given an additional instruction to pay closer attention to offset trials to determine if this expectation would assist in creating a stronger bias toward offsets. Participants read the instruction on the computer screen that people generally find object onsets more quickly and accurately than object offsets, but that in this experiment, they should focus more attentively on object offsets than onsets. Aside from this instruction, the design of this condition was identical to that of the skewed ratio condition.

2.4 *Procedure*

This experiment used the same procedure as in Donaldson and Yamamoto (2011), which adopted the one-shot flicker paradigm developed by Cole et al. (2003). Participants sat in front of a computer screen, centered in front of a button box. The button on the left was labeled “Left”, and the button on the right was labeled “Right”. The participants were told that they would be viewing a series of photograph pairs in which an object would change between two images of each pair. They were also instructed that the change would be either an onset of a new object or an offset of an existing object. They were instructed to press either the left button or the right button, depending on where on the screen the change occurred. They used their left index finger to press the left button and their right index finger to press the right button. They were cautioned to be as quick, but as accurate as possible. They were run individually.

Figure 1 illustrates the trial sequence. In each trial, participants first viewed a fixation cross for 1000 ms that was presented at the center of the screen. They were instructed to keep fixating on the cross while it was displayed and maintain their fixation around the same area after the cross disappeared. They then viewed a first image for 1200 ms which was either missing an object on one side of the screen (onset trial), or included all eight objects (offset trial). The first gray screen was displayed briefly for 100 ms in order to produce the one-shot flicker of the scene. The second image was then displayed for 1200 ms, which was either missing an object on one side of the screen (offset trial), or included all eight objects (onset trial). At the onset of the second image, participants were allowed to make a button press indicating which side of the screen they believe the change occurred. Following the presentation of the second image, a final gray screen was displayed and remained on the screen until the participant made his or her response. Reaction time was recorded between the appearance of the second image and the participant's button press. Accuracy in the left/right judgment was also measured based on participants' button press response. When the participant made an error in the left/right judgment, reaction time from such a trial was not included in the reaction time analysis. After finishing all trials, they completed a handedness inventory (Oldfield, 1971) to provide numerical measures of their handedness due to the nature of the left/right judgment task.

2.5 *Data analysis*

To test if the hypothesis was supported by the data, 2 (trial type: onset or offset) x 3 (condition) mixed analyses of variance (ANOVA) were separately conducted for reaction time and accuracy. Trial type was a within-participant factor, and condition was a between-participant factor.

CHAPTER III

RESULTS

Participants were excluded from the analysis if their mean accuracy in the left/right judgment task for either onset or offset trials was more than two standard deviations away from the mean. Six participants were removed (one from the neutral condition, two from the skewed ratio condition, and three from the skewed ratio with instruction condition), and their mean accuracy for onset and offset trials were 89.58% and 72.66%, respectively. After removing these six participants, four individual data points that exhibited reaction times shorter than 100 ms were removed from the reaction time analysis because it is not usually possible to detect changes in such a short time. Mean reaction times were then computed for each trial type (onset or offset) and for each condition, based on trials in which correct responses were made.

3.1 *Reaction time*

Mean reaction times are plotted in Figure 2A as a function of trial type and condition. Although participants in the skewed ratio and skewed ratio with instruction conditions were expected to experience less of a disadvantage during offsets trials against onset trials as a result of the offset bias manipulation, onset trials still yielded shorter reaction times in all three conditions. Consistent with this observation, neither an interaction between trial type and condition, nor the main effect of condition were significant, F (2, 51) = 0.083, p = .920, η_p^2 = .003, and F (2, 51) = 1.624, p = .207, η_p^2= .060, respectively. The main effect of trial type was significant, F (1, 51) = 128.568, p < .001, η_p^2= .716.

A planned comparison between onset and offset trials within the neutral condition indicated that onsets were detected more quickly than offsets when no bias was introduced, t (18) = 5.247, p < .001, showing onset primacy as predicted.

3.2 *Accuracy*

Mean accuracies are plotted in Figure 2B as a function of trial type and condition. Participants in the skewed ratio and skewed ratio with instruction conditions were expected to experience less of a shortcoming during offsets trials against onset trials due to the offset bias manipulation, however, onset trials still yielded higher accuracy in all three conditions. Offset accuracy was marginally higher in the skewed ratio and skewed ratio with instruction conditions compared to offset accuracy in the neutral condition. Neither an interaction between trial type and condition, nor the main effect of condition were significant, F (2, 51) = 0.357, p = .702, η_p^2 = .062, and F (2, 51) = 1.336, p = .272, η_p^2= .050, respectively. The main effect of trial type was marginally significant, F (1, 51) = 3.369, p = .072, η_p^2= .062.

A planned comparison between onset and offset trials within the neutral condition showed that there were no significant differences in mean accuracy for onset and offset trials, $t(18) = 1.664$, $p = .114$.

CHAPTER IV

DISCUSSION

Overall, neither reaction times nor accuracy were modulated significantly by the manipulation. In this experiment, one prediction was for participants in the skewed ratio and skewed ratio with instruction conditions to show less of a disadvantage during offset trials compared to onset trials because of the offset bias manipulation, compared to participants in the neutral condition who did not experience a bias. A potential pattern of results from the present study was for participants who experienced the bias to show shorter reaction time and higher accuracy for offsets compared to performance during offset trials of participants in the neutral condition, but still detect onsets more quickly and accurately than object offsets. Although the data seem to be consistent with this pattern of results, the experiment did not have enough power to reliably detect this trend. Compared to participants in the neutral condition, participants in the skewed ratio and skewed ratio with instruction conditions showed smaller differences in accuracy between onsets and offsets. This finding was mainly due to better accuracy for offset trials for participants in the skewed ratio and skewed ratio with instruction conditions. On the other hand, reaction times did not change much across the three conditions, but participants in the skewed ratio and skewed ratio with instruction conditions showed slightly shorter reaction times for offsets, compared to participants in the neutral condition. These two trends indicate a low likelihood of a speed-accuracy tradeoff because better accuracy for offset trials in the skewed ratio and skewed ratio with instruction conditions did not come at the expense of longer reaction times.

An additional prediction of the present study was that participants in the skewed ratio and skewed ratio with instruction conditions would have an impaired ability to detect onsets under offset bias due to a shift from the default attentional mode. This prediction was not supported by the data because participants in the skewed ratio and skewed ratio with instruction conditions still showed higher accuracy on onset trials than offset trials, and shorter reaction times on onset trials than offset trials. Participants in the skewed ratio and skewed ratio with instruction conditions may have implicitly experienced more focused attention throughout the experiment overall, demonstrating improved performance even on onset trials. Furthermore, the offset bias used in the present study may not have been strong enough to completely shift the current attentional mode of participants in the skewed ratio and skewed ratio with instruction conditions.

Although reaction time and accuracy data did not reach the level of statistical significance, the trend that was suggested by both measures is promising that perhaps altering the state of one’s attentional system can affect the type of change in visual stimuli (onsets or offsets) that will better capture attention. It is necessary to increase the power of the present study in order to find a more convincing pattern of results to support the presence of offset bias in certain visual-attentional situations. A major limitation of the study was the sample size, so increasing the number of participants in all conditions would be one direction. Also, increasing the strength of the prime, perhaps by showing an increased amount of offset trials in block one for the skewed ratio and skewed ratio with instruction conditions, might elicit larger differences in performance.

It is not yet known precisely how many trials are necessary to undergo in order to induce bias, however, after only 36 additional offset trials in block one of the experiment, participants in the skewed ratio and skewed ratio with instruction condition showed a trend in which they had less of a disadvantage during offset trials than participants in the neutral condition. It is important to note that participants' performance on accuracy and reaction time in the skewed ratio with instruction condition was not enhanced by the additional instruction, compared to participants in the skewed ratio condition. The instruction given to participants in the skewed ratio with instruction condition was intended to make them consciously attend more fully to offsets than onsets. However, the instruction did not seem to have an effect on successful induction of offset bias above the bias found in the skewed ratio condition. Implicit exposure to additional offset trials in the first block of the experiment might be sufficient to prime an offset bias in participants in the skewed ratio condition. Regarding human visual cognition, this suggests that our attentional system may switch between prioritizing onsets and offsets, based on environmental factors, automatically and remarkably quickly. Explicitly and consciously directing focused attention on onsets or offsets when detection of onsets or offsets is of high priority may be unnecessary. Human visual cognition may automatically direct attention to the visual events that are important in a given situation without our awareness or effort.

Future research is needed to determine the extent to which offset primacy or onset primacy will occur in situations that demand more attentional resources for one type of visual event over the other. It is necessary to understand the mechanism by which individuals may be able to more quickly direct their attention. For detection of onsets to be meaningfully useful, it often needs to take place very quickly, to avoid a collision or a predator, for example. On the other hand, detection of other types of events, such as offsets may not require such “split-second” decisions. As a result, having onset primacy as the default mode makes sense. The ability for the attentional system to adapt to other types of visual events, such as offsets, to meet the attentional demands of a situation would also be advantageous. If evidence of this attentional flexibility were found, then that ability would serve the evolutionary purpose of being able to attend to the type of visual event that is presently most advantageous to maximize the probability of survival.

Determining the duration of the bias after the prime may be an important next step in learning about the underlying mechanisms that enable the attentional system to adapt effectively. Furthermore, investigating how the attentional system copes under particularly stressful or threatening situations may also be important because heightened performance in this study was not linked to an emotional reward or advantage.

The present study tested observers’ change detection ability in a naturalistic, but still controlled viewing condition. Compared to previous work that mainly used computer-generated abstract displays as experimental stimuli (e.g., Cole et al., 2003), the use of real photographs is a significant improvement. Furthermore, the neutral condition of the present study replicated onset primacy findings of Donaldson and Yamamoto (2011), strengthening their finding that onset primacy can be observed with naturalistic visual stimuli. To build on the strengths of the present study, it is important to make the present study even closer to real-world situations because knowledge of what effectively captures attention in a laboratory setting can be used to train people in occupations that require careful attention to a particular visual event (e.g., surveillance). One way to bridge laboratory settings into real-world situations would be to develop experiments in which scenes with more objects in a more complicated layout are used as experimental stimuli. In fact, such images are more similar to the stimuli used in typical change blindness studies (e.g., Rensink et al., 1997). Another interesting approach toward increasing the validity of the present findings would be to conduct the same experiment by utilizing actual objects and events in a public place.

The most influential implication of the present study is that humans can adapt, and that the relationship between attention and vision is sufficiently flexible to enable people to notice what they need to notice on an ongoing basis. Results of this study signify that humans' attentional systems can designate the appropriate mode of attention to use depending on a particular context.

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APPENDIX

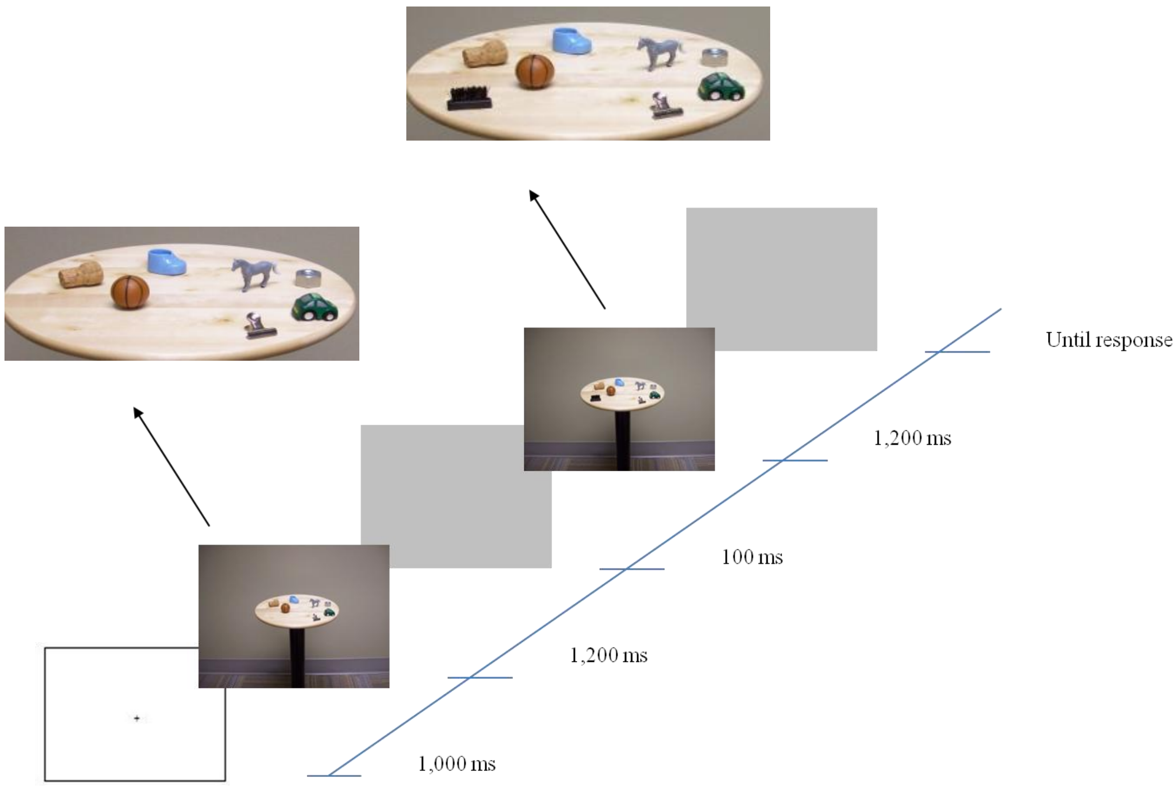

Figure 1. The trial sequence. In this example, an object (the brush) is added to the second scene on the left-hand side. This is an onset trial. Pictures in the trial sequence are actual pictures that were used in the experiment. Larger pictures are close-up views of the object array.

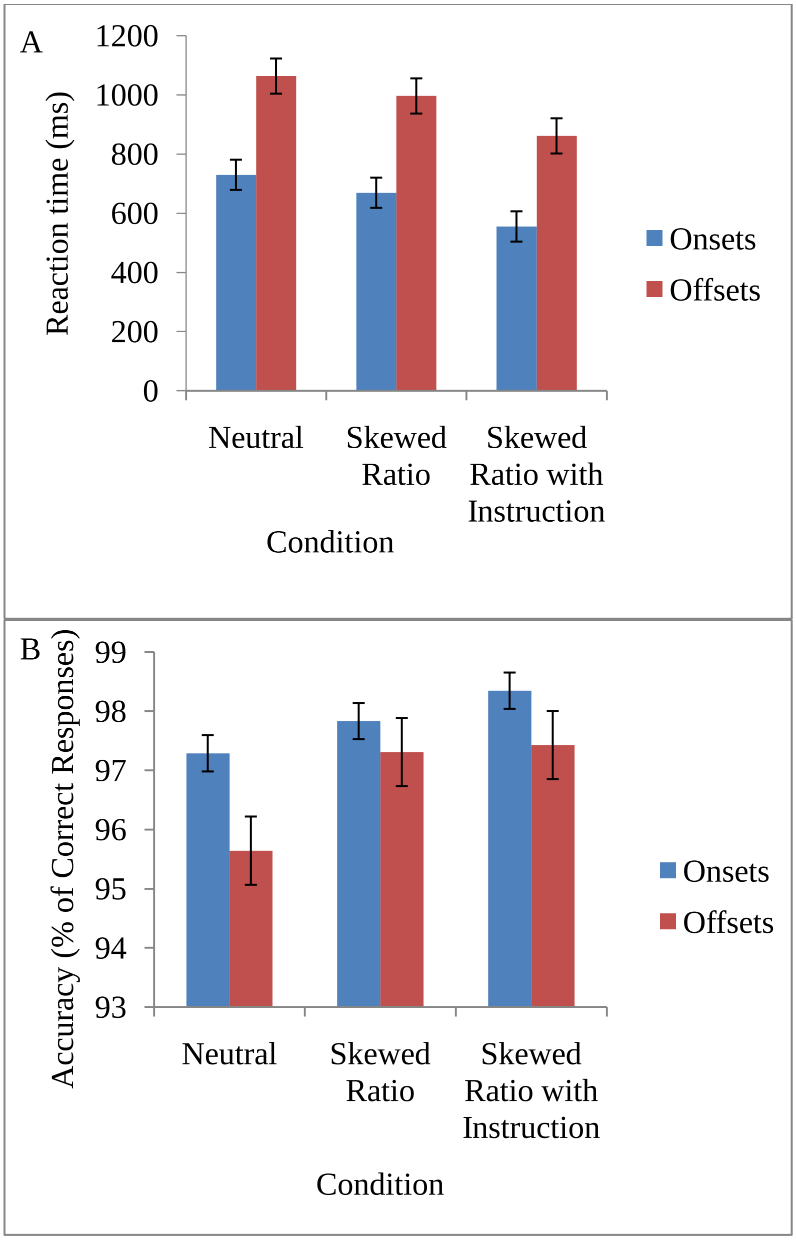

Figure 2. Mean reaction time (A) and accuracy (B) as a function of condition and trial type. Error bars represent ±1 standard error of the mean.